Title
Technology Development on ISS for Satellite Servicing and Exploration

Topic
Technology Development and Demonstration

Short abstract (100 word limit):

NASA's Satellite Servicing Capabilities Office is utilizing the International Space Station to demonstrate technologies essential to satellite servicing endeavors in support of human exploration and science. Within this presentation, we will discuss the status and implications of three of these technology payloads: Raven, Robotic Refueling Mission (RRM) Phase 2, and RRM Phase 3.

Long abstract (500 -1000 words)

NASA's Satellite Servicing Capabilities Office (SSCO) is utilizing the International Space Station to demonstrate technologies essential to future capabilities for science and human exploration. Within this presentation, we will discuss the status and implications of three of these technology payloads: Raven, Robotic Refueling Mission (RRM) Phase 2, and RRM Phase 3.

Raven, a demonstration launching to the space station in 2016, is helping to establish a core technology suite for rendezvous and proximity operations by maturing sensors, avionics and algorithms essential for autonomous rendezvous with non-cooperative objects. The Raven technology demonstration includes sensors in three separate wavelengths, radiation-tolerant processing hardware, as well as advanced pose algorithms. Raven data will directly benefit the development of an RPO system for satellite servicing. That same RPO system, in turn, has been baselined for both the capture and crewed vehicles for the Asteroid Redirect Mission, currently under consideration by NASA. Such a technology suite could also offer unique benefits to many potential servicing missions, such as large-telescope assembly, as it would provide an autonomous rendezvous and docking capability for manned and unmanned logistics tugs. Within this presentation, we will provide a status update on Raven's progress and discuss the opportunities it offers to the aerospace community.

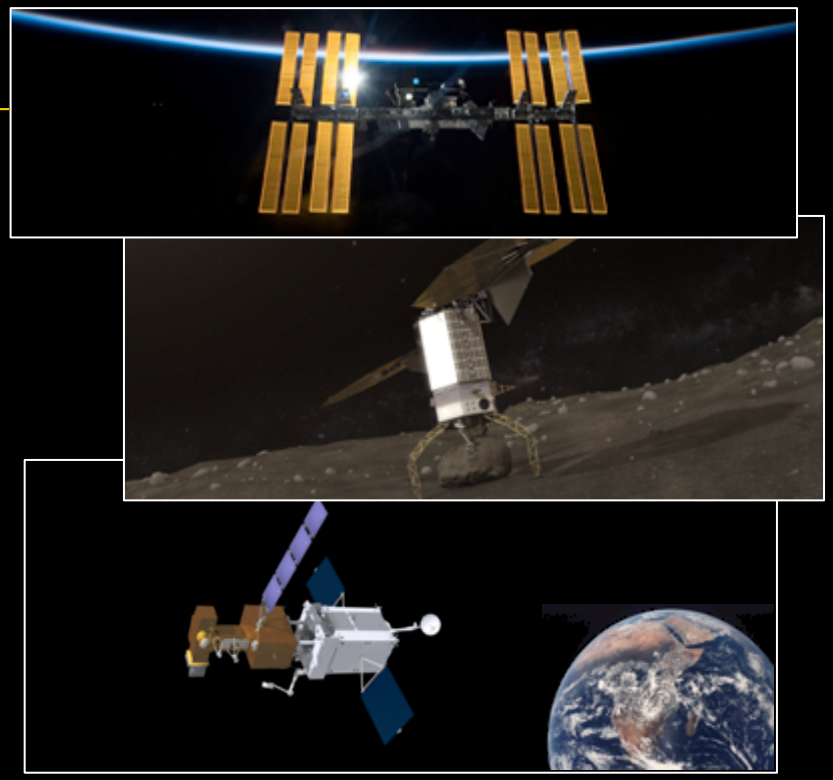
Operations for the second phase of the Robotic Refueling Mission are slated to take place on the International Space Station in spring 2015. Activities include testing a new inspection tool, practicing intermediary steps leading up to cryogen replenishment, testing electrical connections for "plug-and-play" instruments, and working with reflective decals that could help operations guided by machine vision. The common thread to these diverse tasks is the expansion of servicing capabilities. These new technologies, tools and techniques could eventually give satellite owners resources to diagnose problems on orbit, fix anomalies, and keep certain spacecraft instruments

performing longer in space. We will present results from the spring 2015 operations and explore how these capabilities, tested on the International Space Station test bed, can benefit various aerospace endeavors.

As a proof of concept demonstration, SSCO is currently planning RRM-3, which will demonstrate xenon transfer on an external platform mounted to ISS. The demonstration would transfer high-pressure, supercritical xenon gas across a robotically mated valve, which is being custom designed to support cooperative robotic transfers on future spacecraft. The successful demonstration of these technologies will lay a foundation for extensibility to larger volume applications, such as the Asteroid Redirect Mission. A second area of focus will be to test a newly designed cryogen coupler. This coupler would be the primary interface between a servicing vehicle and an exploration vehicle in need of replenishment. The coupler demonstration on RRM-3 will show that a mechanism can be robotically installed with minimal actuation that is capable of creating a sealed interface for the transfer of liquid cryogens. While the RRM-3 demonstration will be robotic only, one goal of the design is to allow simple crossover to a human-actuated interface. Within this presentation, we will present a brief overview of the payload as currently designed.

The International Space Station has provided an unparalleled platform on which to test this suite of technologies. Within the descriptions of these three payloads, we will highlight the benefits and efficiencies that have resulted from using the space station as the proving ground for these capabilities.

Technology Development on ISS for Satellite Servicing and Exploration



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Benjamin B. Reed
Deputy Project Manager
Satellite Servicing Capabilities Office
http://ssco.gsfc.nasa.gov

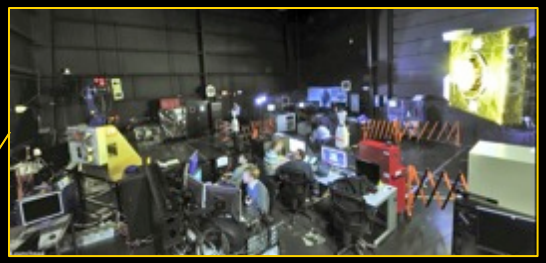
In Space Robotic Servicing

- The Satellite Servicing Capabilities Office is responsible for the overall management, coordination, and implementation of satellite servicing technologies and capabilities for NASA. To meet these objectives we:
  - Study point design notional missions
  - Build hardware/software for experiments in orbit and on the ground
  - Manage technology development campaign and servicing missions
  - Design and advise cooperative servicing elements

In Space Robotic Servicing Team and Partners

Canadian Space Agency

Johnson Space Center

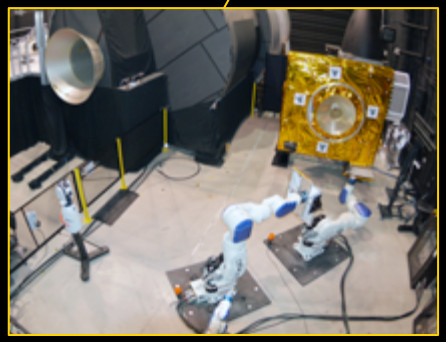


Goddard Space Flight Center

Department of Defense Space Test Program

Glenn Research Center

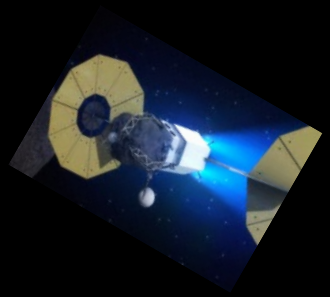
Naval Research Laboratory

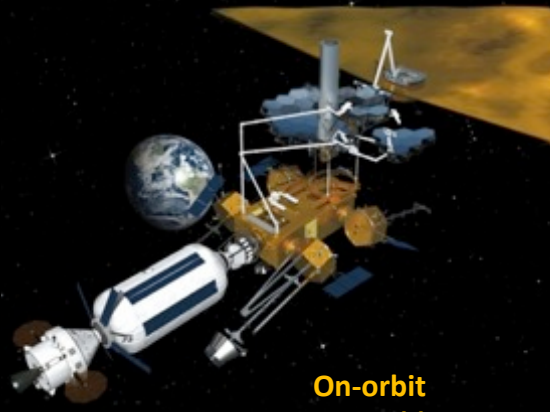


WVU
RPI
JHU
UMD

Kennedy Space Center

Servicing Supports Multiple Objectives





On-orbit Assembly

Asteroid Redirection

Infrastructure Inspection and Maintenance

Fleet Management Government and Commercial

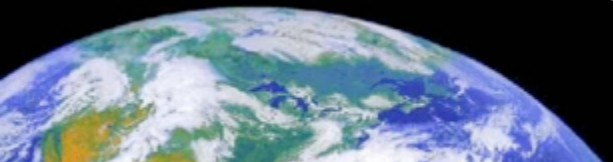
Human Exploration

Observatory Servicing

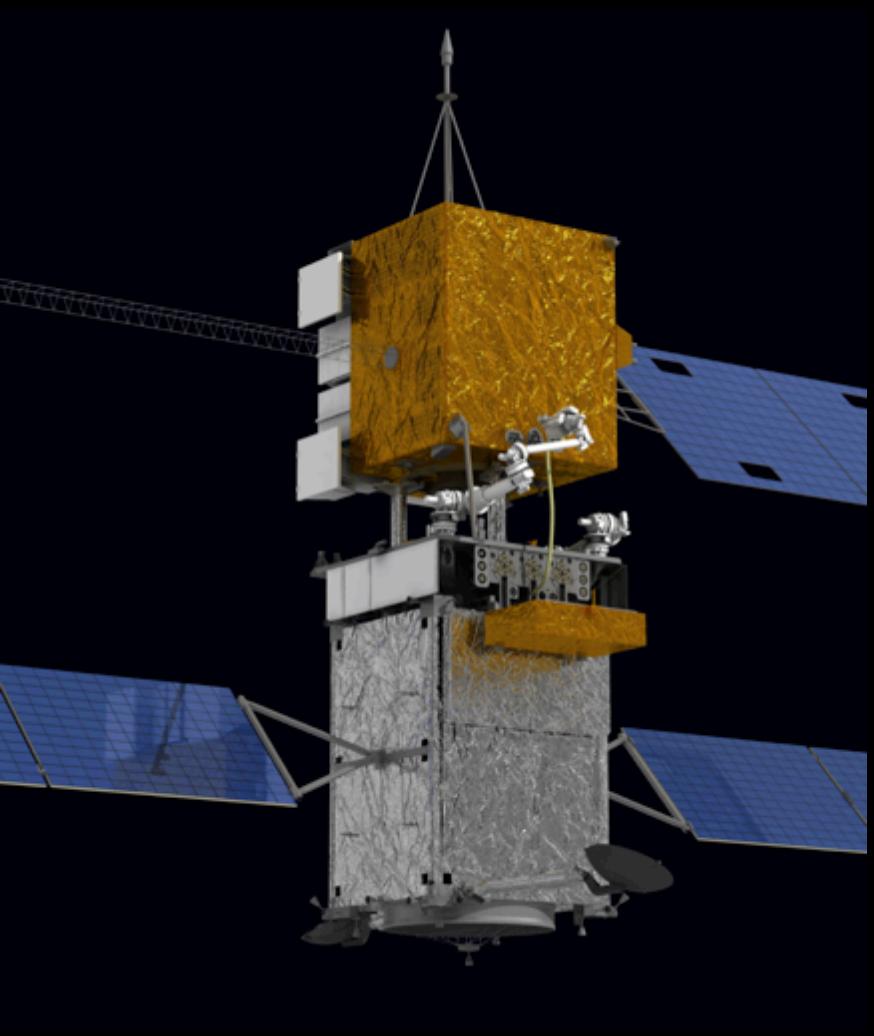
Planetary Defense

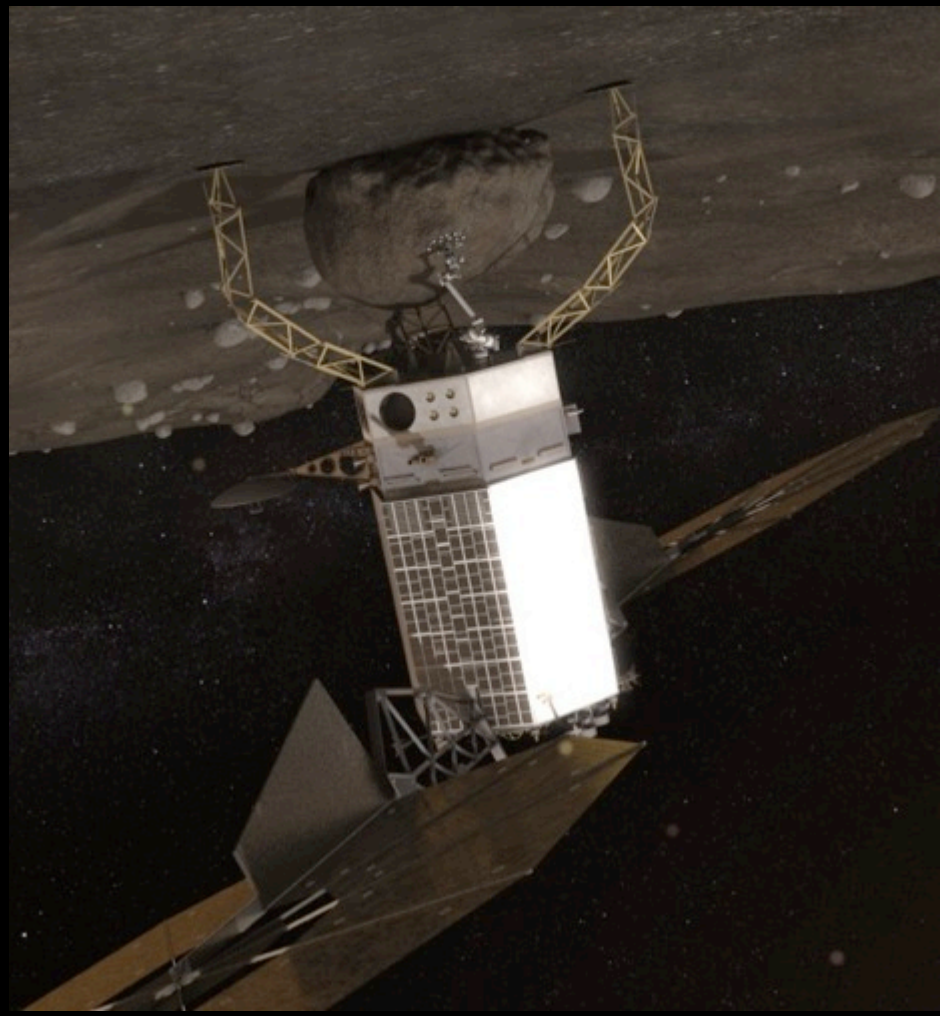
Servicing Capabilities

Propellant Depot



Restore-L and Asteroid Redirect Robotic Mission (ARRM)

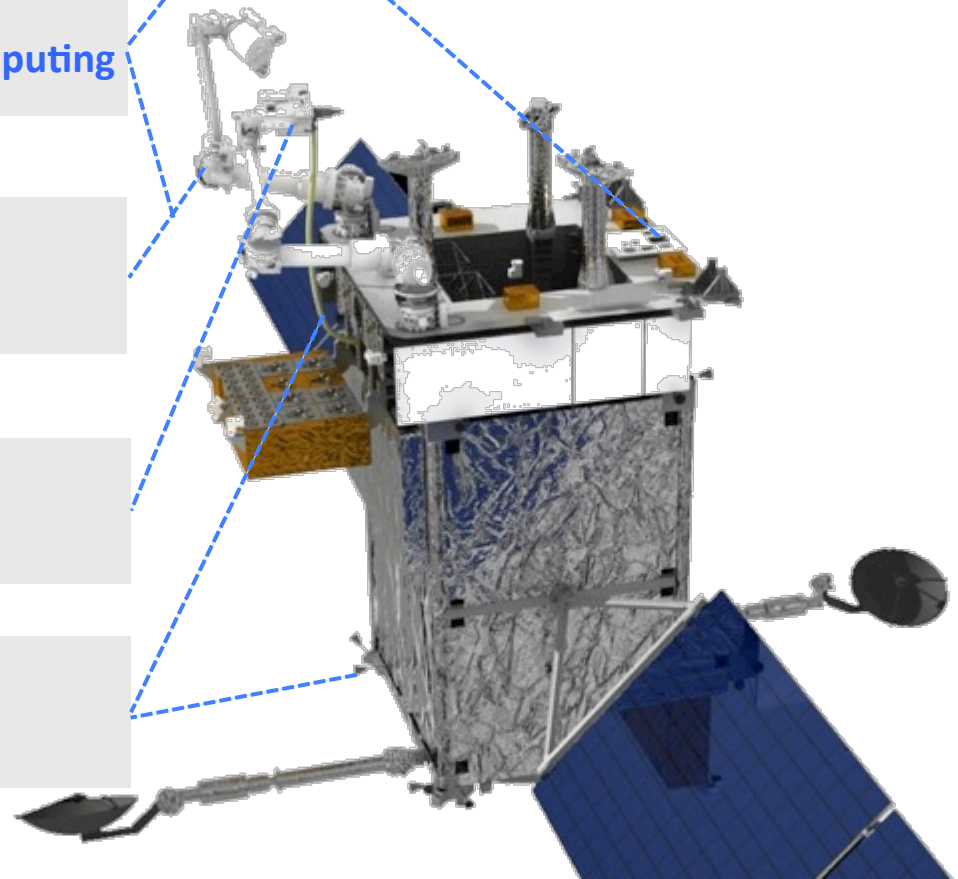




Artist's concepts

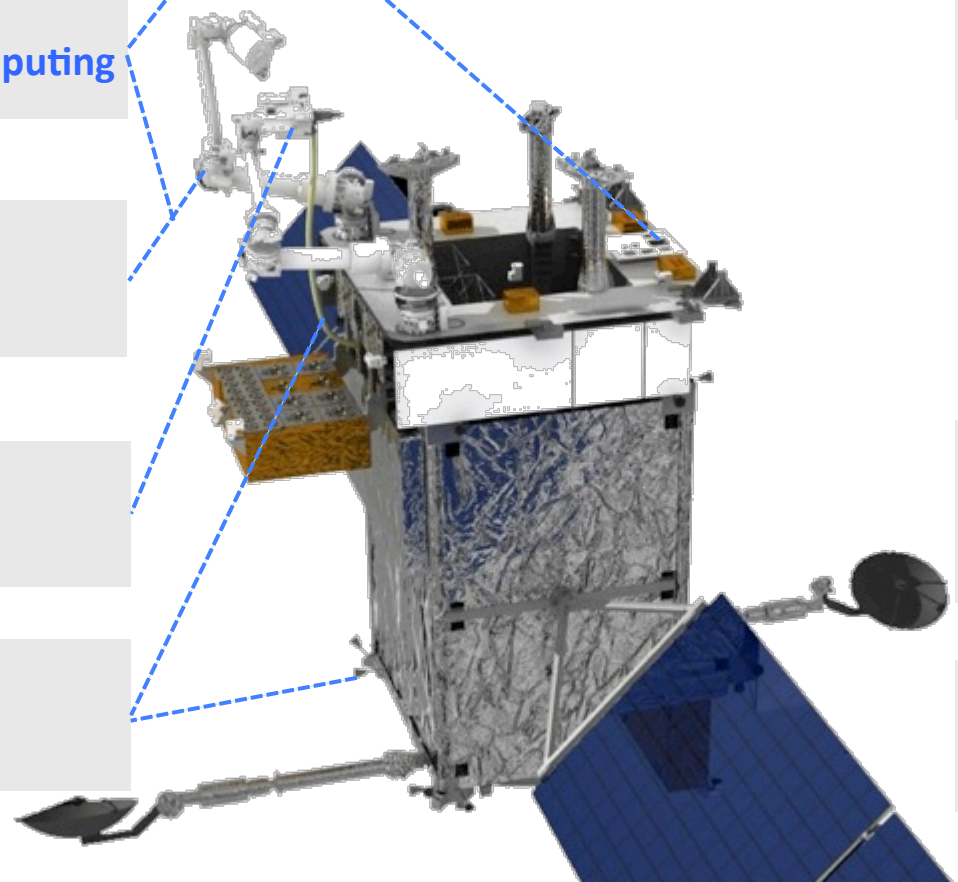
Critical Technologies

- Rendezvous & Prox Ops System
- High-speed, Fault-Tolerant Computing
- Dexterous Robotics
- Robotic Tools and Tool Drive
- Fluid Transfer



Critical Technologies

Rendezvous & Prox Ops System	Raven
High-speed, Fault-Tolerant Computing	Raven
Dexterous Robotics	
Robotic Tools and Tool Drive	Robotic Refueling Mission (RRM), RRM-2, RRM-3
Fluid Transfer	RRM, RRM-3



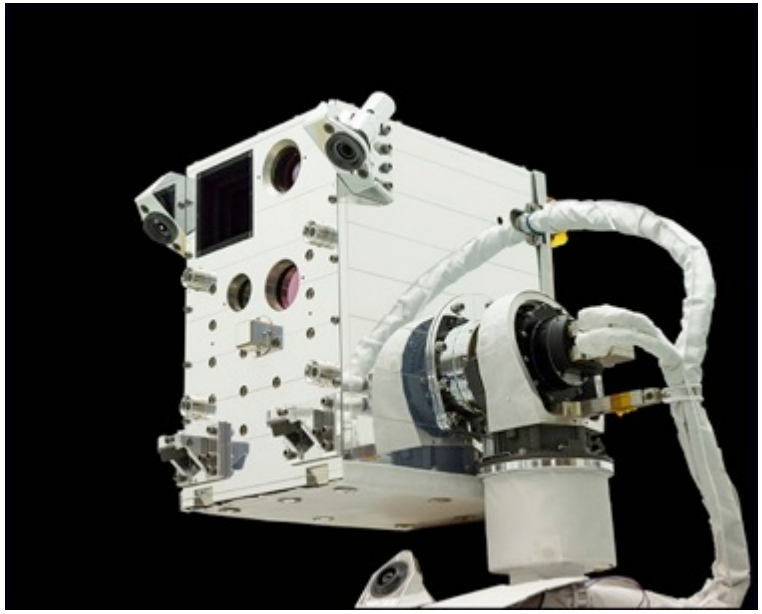
Raven

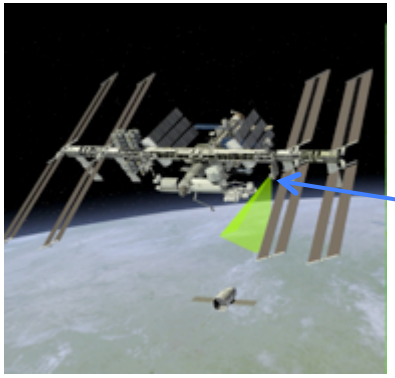
Raven is an ISS technology demonstration of system-level technologies applicable to accomplish cooperative and non-cooperative relative navigation.

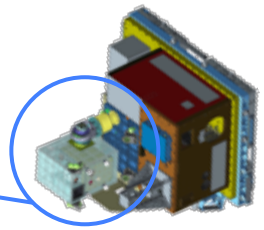
Complex, but compact, hardware complement

- Two-axis gimbal provides sensor pointing
- Relative navigation sensors provide tracking in three bands – visible, IR, and lidar
- State-of-the-art pose algorithms provide relative position and attitude measurement of the visiting vehicle relative to each sensor
- High-performance avionics provide efficient, reliable, and reconfigurable computing environment
- Navigation algorithms provide an optimal estimate of the relative state – position, velocity, attitude, and rate – based on data from all the sensors

Two-year mission provides upwards of 60 relative navigation tracking events (rendezvous and departures).

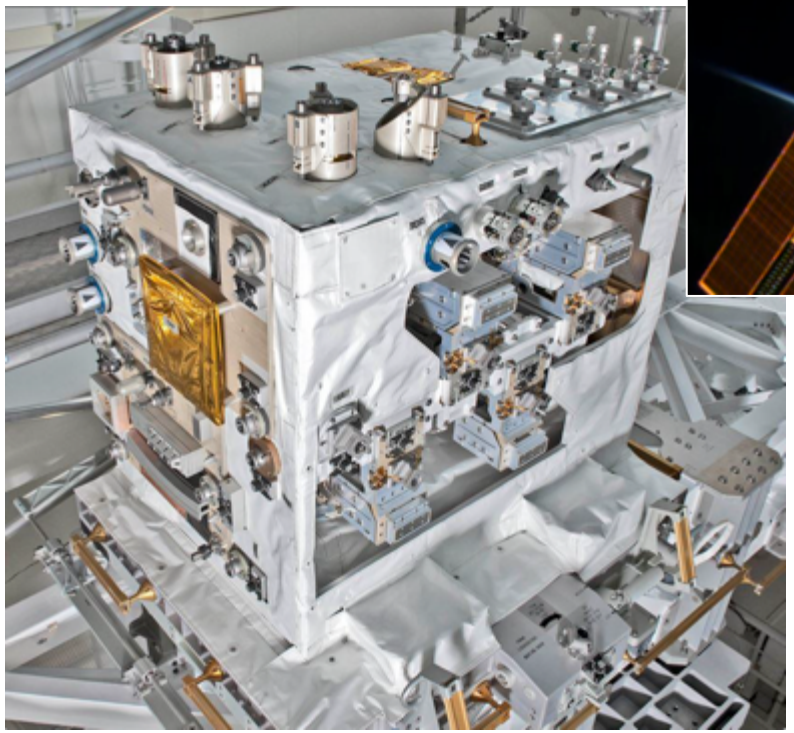


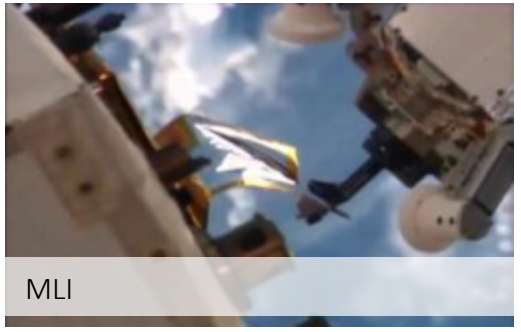




Raven flies aboard STP-H5, a complement of experiments integrated and flown under the management and direction of the DoD's Space Test Program.

Robotic Refueling Mission (RRM)
Phase 1 Operations: 2011-2013



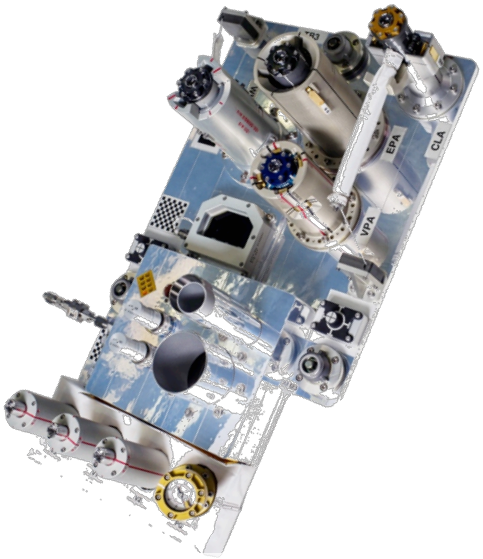


On-orbit robotic demonstrations included:

- Lockwire cutting and removal of fill/drain valve and cap components
- Tape cutting and MLI manipulation
- Fluid transfer through an on-orbit, mated nozzle-to-valve connection

Robotic Refueling Mission (RRM)
Phase 2 Operations: 2015

VIPIR: Visual Inspection Poseable Invertebrate Robot

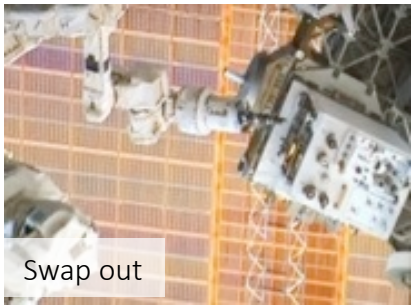


Task Board 3

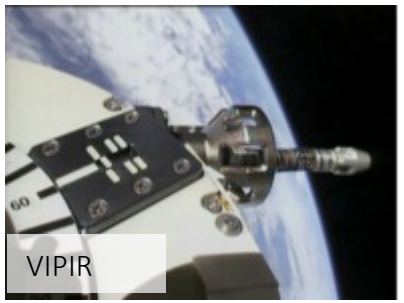
Task Board 4

On-orbit robotic demonstrations include:

- ✓ Inspection capabilities (VIPIR)
- Intermediary steps leading to cryo transfer
- Testing electrical connections for plug-and-play instruments
- Machine vision aids (decals)
- ✓ Solar cell experiment
- Materials coating experiment



Swap out

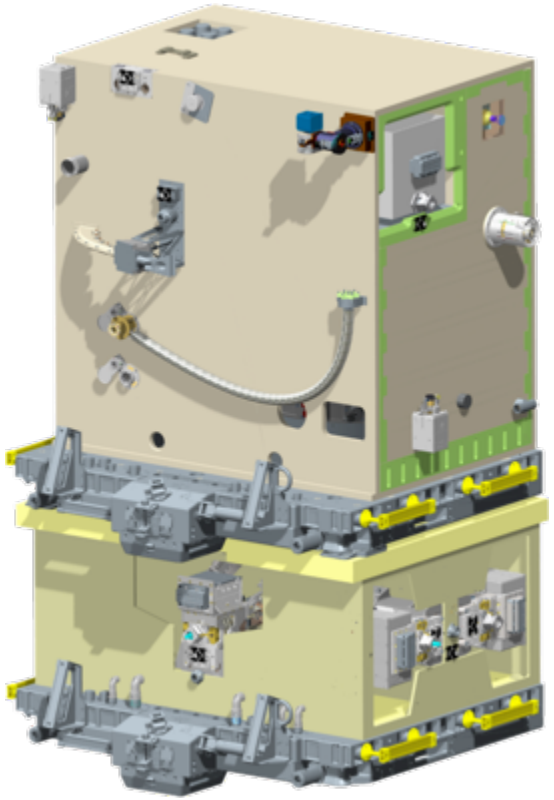


VIPIR

Robotic Refueling Mission
Phase 3: *In work*

On-orbit robotic demonstrations will include:

- Transfer and freeze standard cryogenic fluid via “zero vent” technique, without forming ice plugs
  - For legacy and cooperative interfaces
  - Maintain fluid mass for six months via zero boil-off
- Transfer Xenon gas through cooperative interfaces
- Verify robotic manipulation techniques necessary for cryogenic fluid and Xenon transfers



RRM-3 concept

Cooperative Servicing Aids (CoSA)

CoSA: features that could be incorporated into new satellites to facilitate servicing in the future.

Rendezvous and Proximity Operations

- Features and techniques to increase the reliable and robust rendezvous sequence

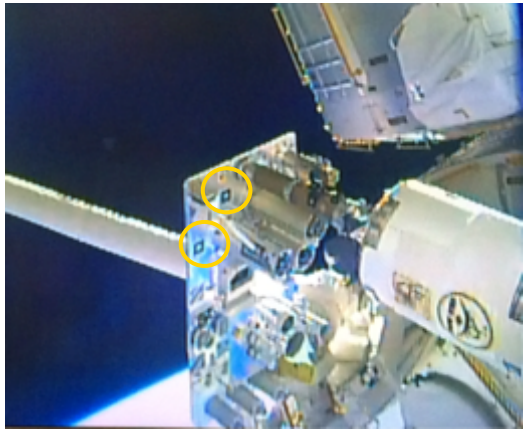
Capture

- Features and markings on client tailored to the capture technique going to be employed by servicer

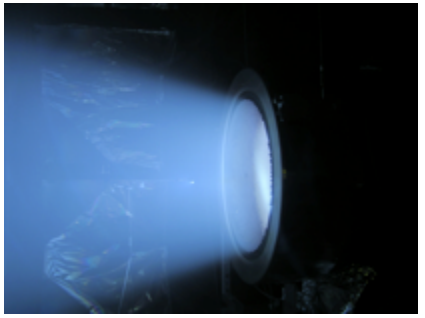
Refueling

- Design external and internal propellant system to be accommodating of refueling
  - Chemical
  - Electric

Fiducial



Cooperative Decal on RRM Task Board

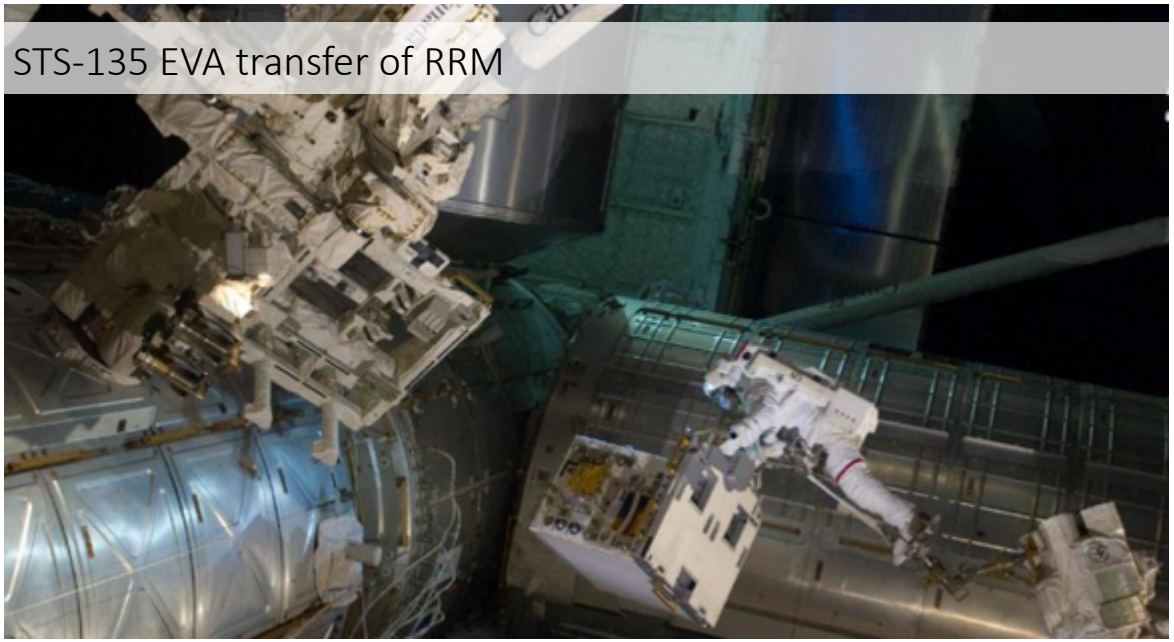


Ion thruster

Placing servicing aids on new spacecraft is an inexpensive way to hedge for a future servicing mission.

Looking Forward

- NASA is has made significant progress with servicing technologies due to the unparalleled on-orbit facilities of the ISS
- This technology maturation advances NASA towards its exploration and scientific goals
- SSCO is looking forward to continued success with its ISS partners
- Stay tuned for resumed RRM operations in 2015; Raven launches in early 2016


STS-135 EVA transfer of RRM